Neural Modularity Helps Organisms Evolve to Learn New Skills Without Forgetting Old Skills

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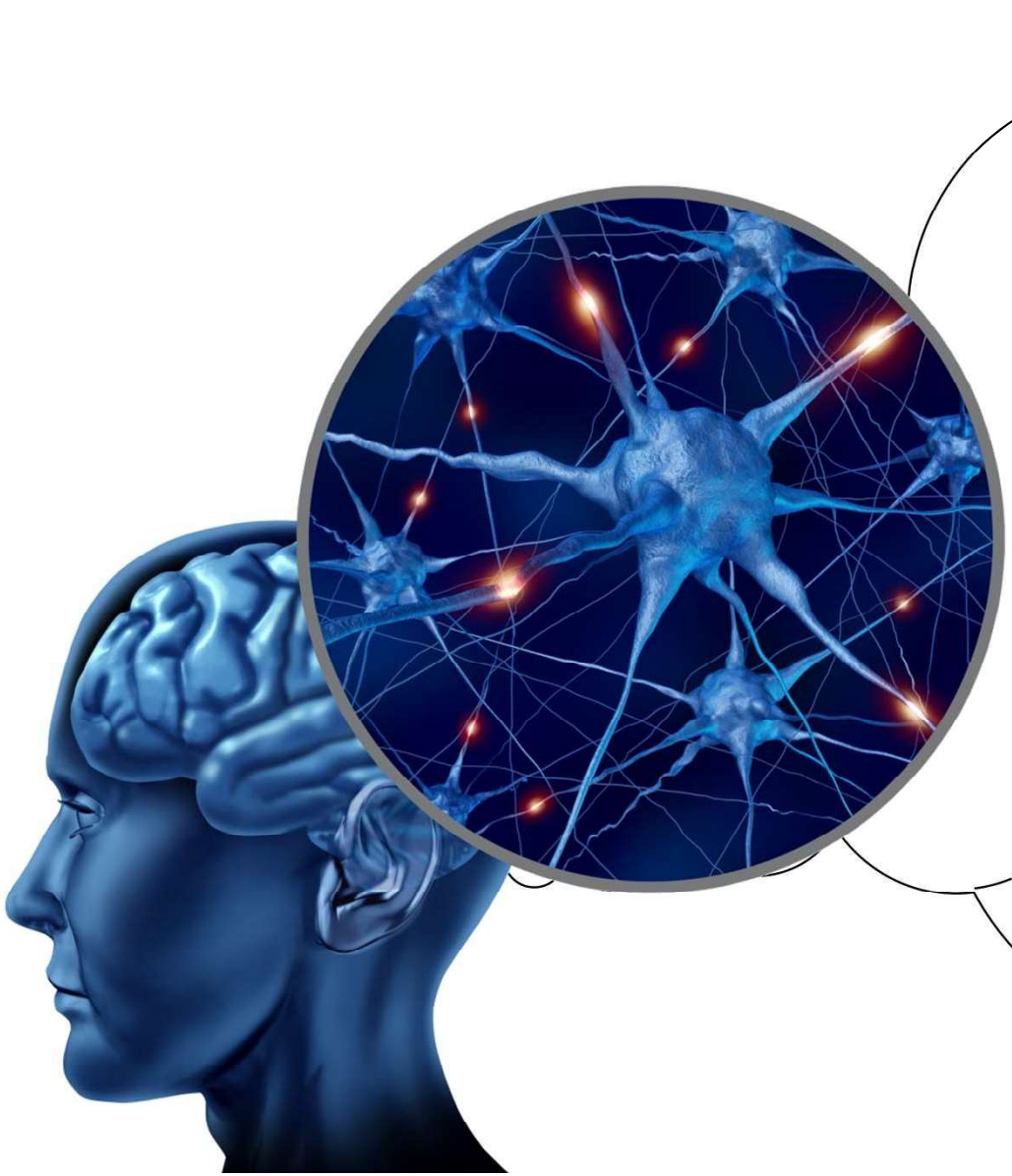
Jeff Clune

Background and Motivation



(Barnes and Underwood 1959)

In Artificial Neural Networks: Catastrophic Interference

CATASTROPHIC INTERFERENCE IN CONNECTIONIST NETWORKS: THE SEQUENTIAL LEARNING PROBLEM

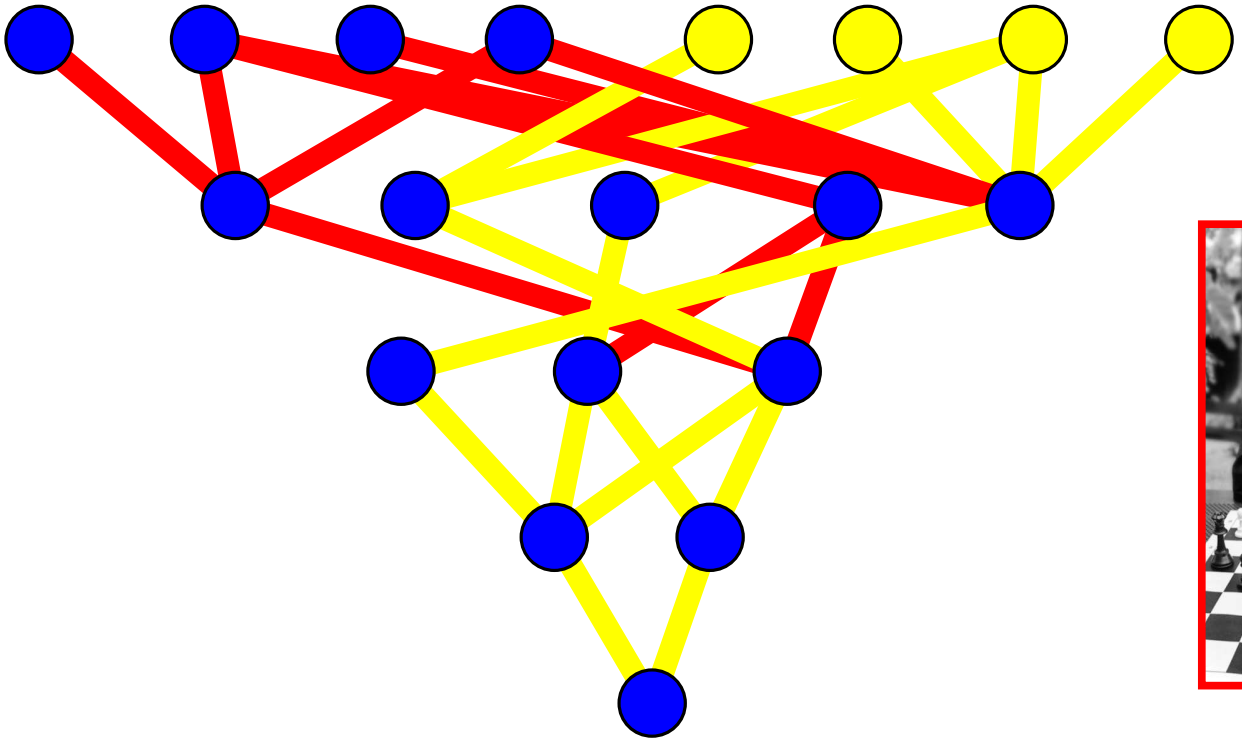
Michael McCloskey
Neal J. Cohen

Connectionist Models of Recognition Memory:
Constraints Imposed by Learning and Forgetting Functions

Roger Ratcliff
Northwestern University

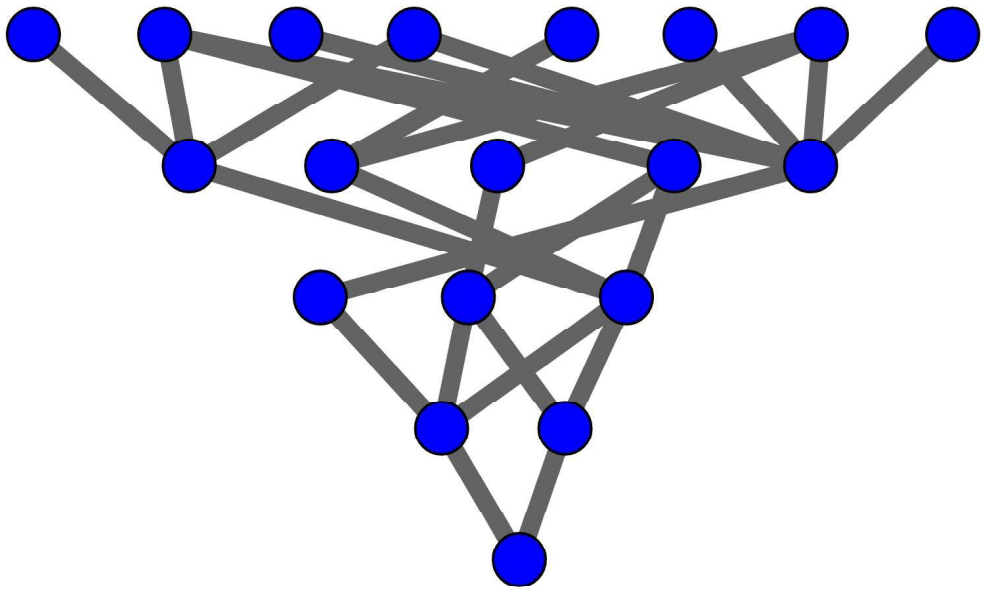
(McCloskey and Cohen 1989)

Learning Skill A then Learning **Skill B**

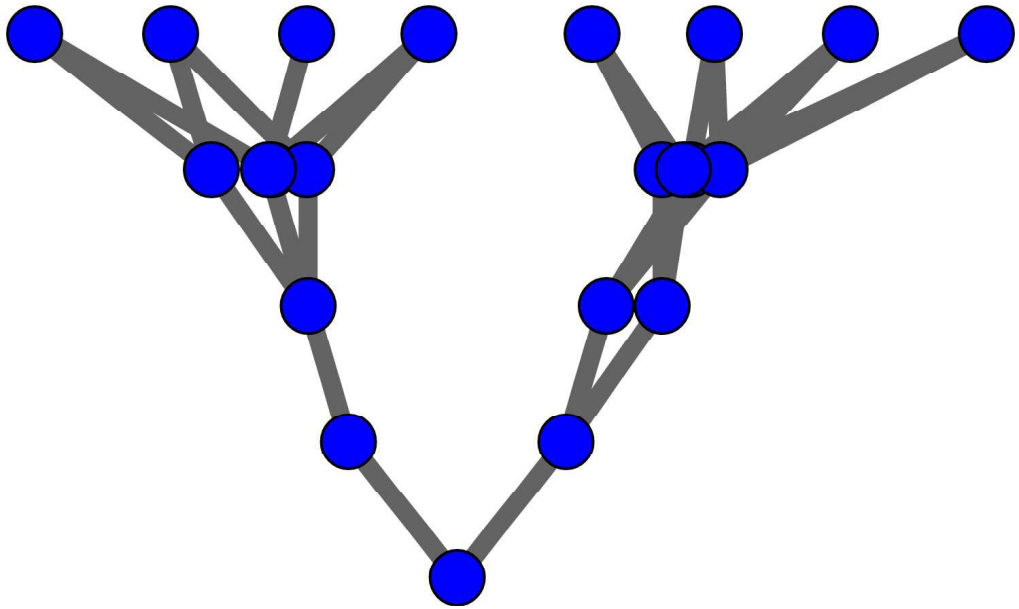


Natural Neural Networks are Modular

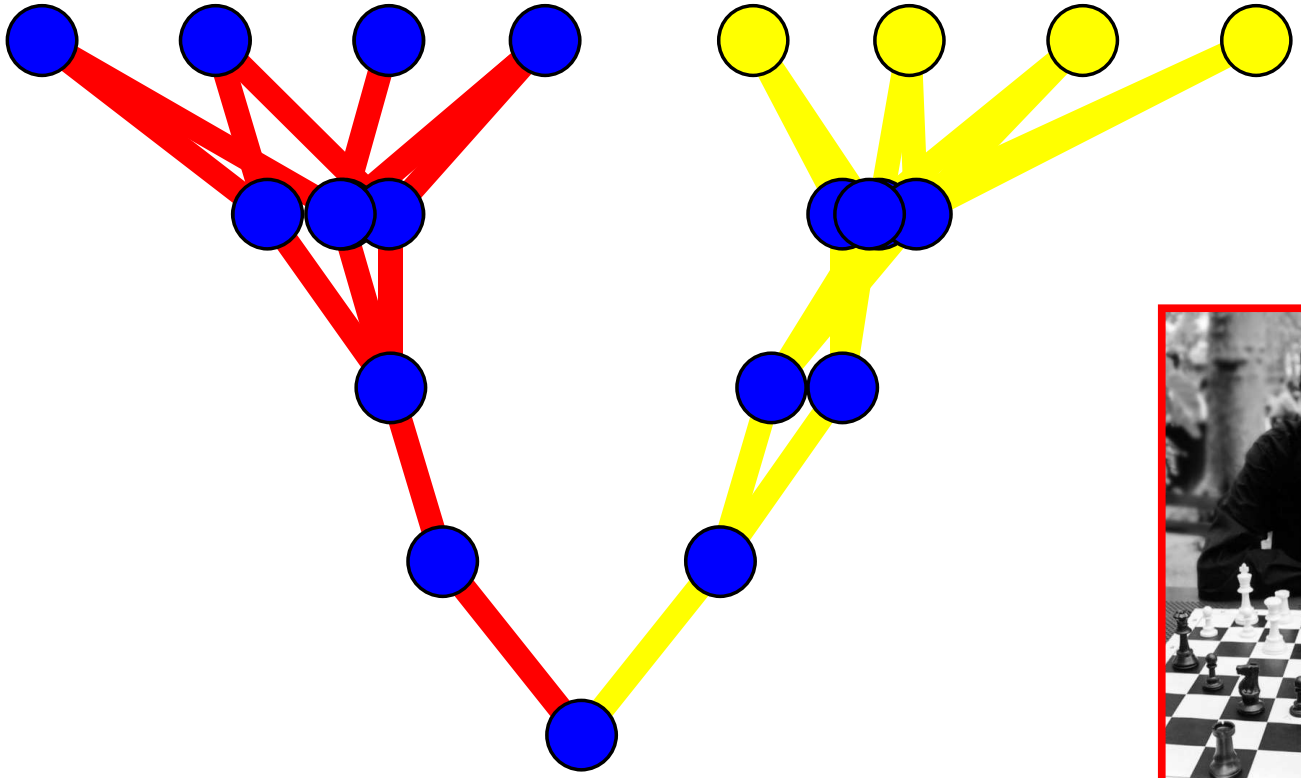
Low Modularity



High Modularity



Modularity Can Reduce Interference



Can We Evolve Modular Neural Networks?

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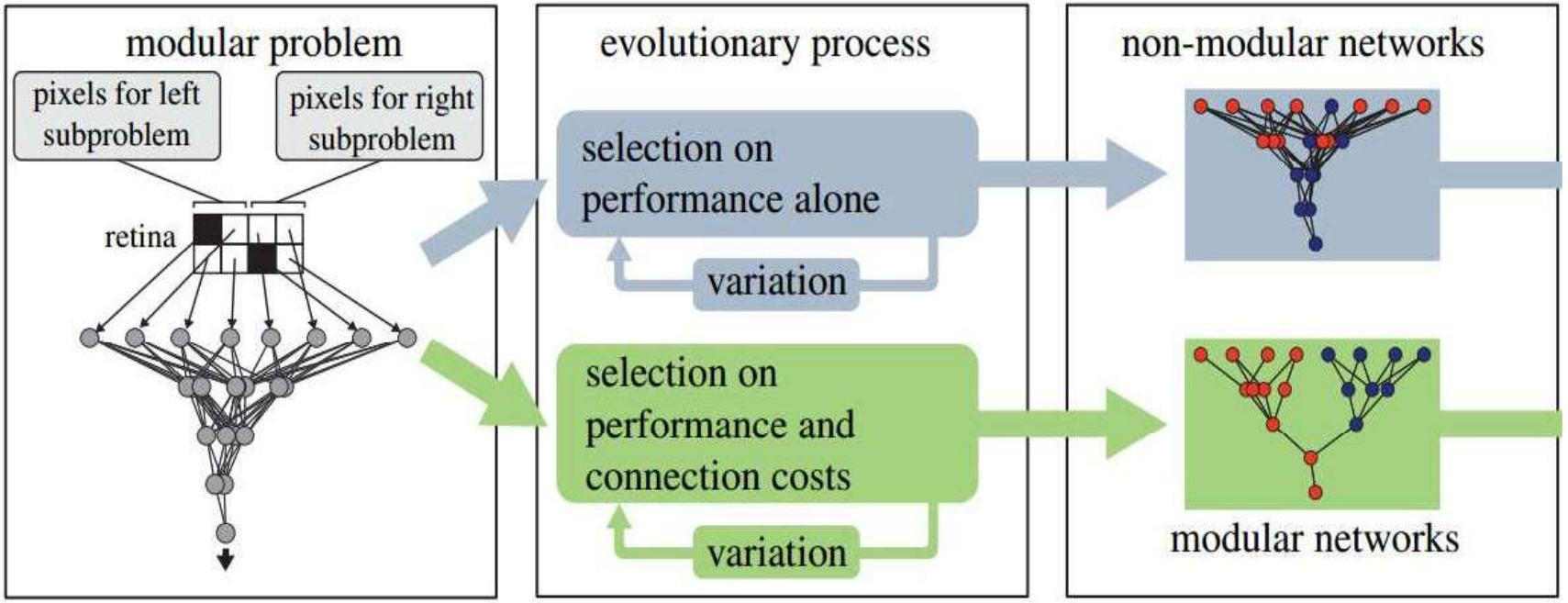
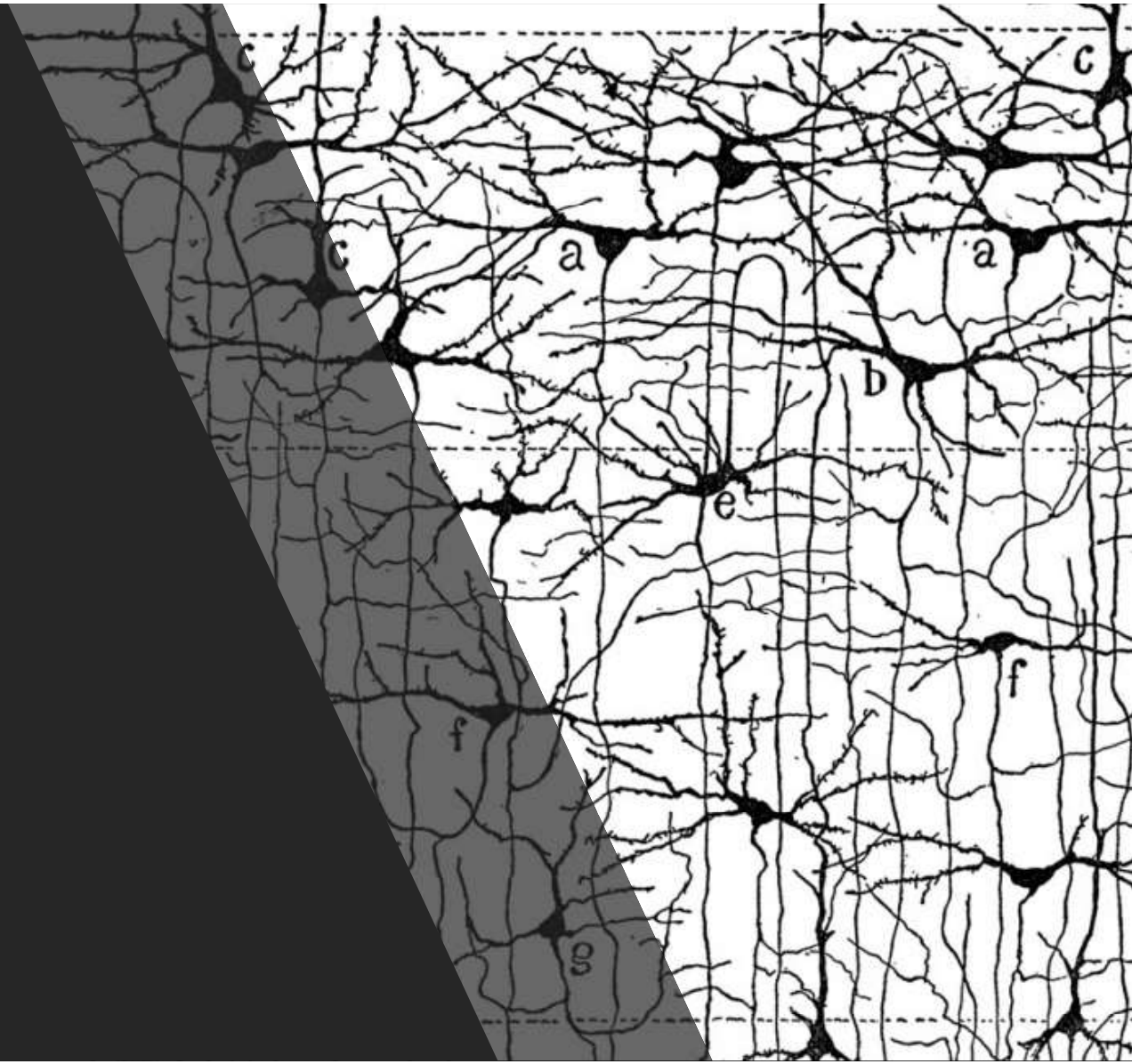
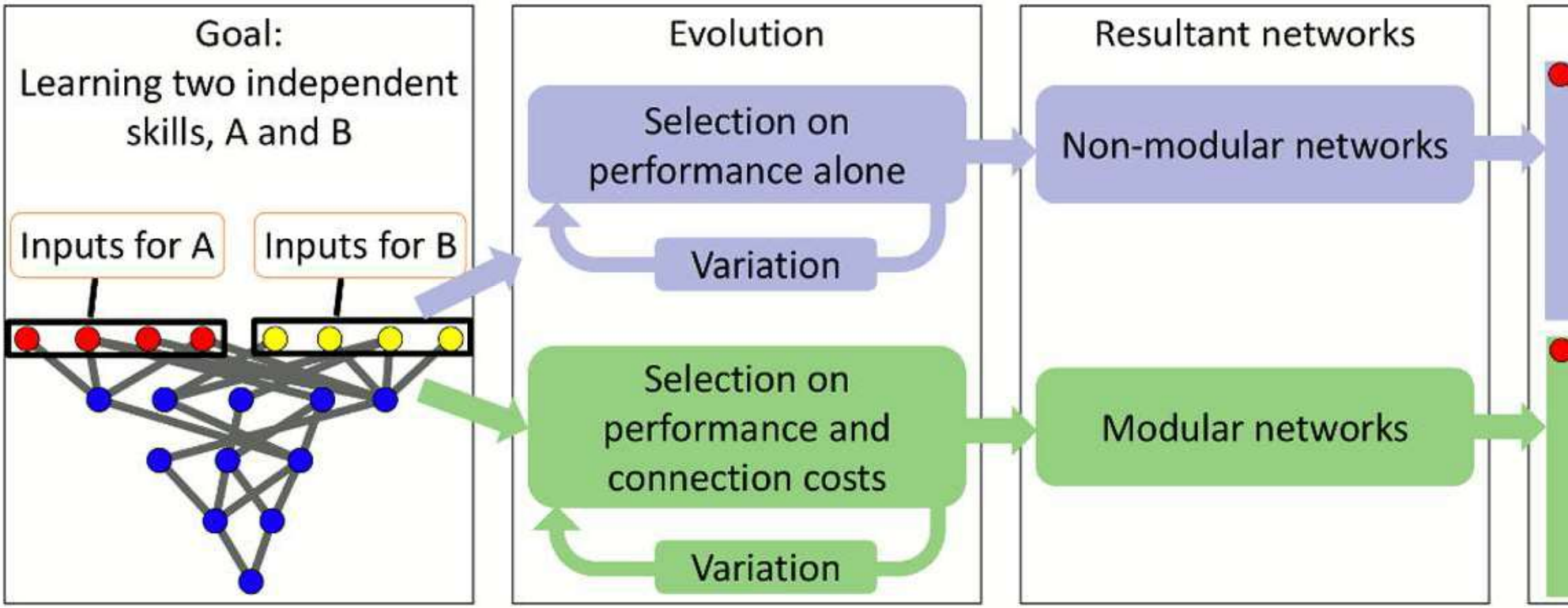


Clune, Mouret and Lipson (2013)

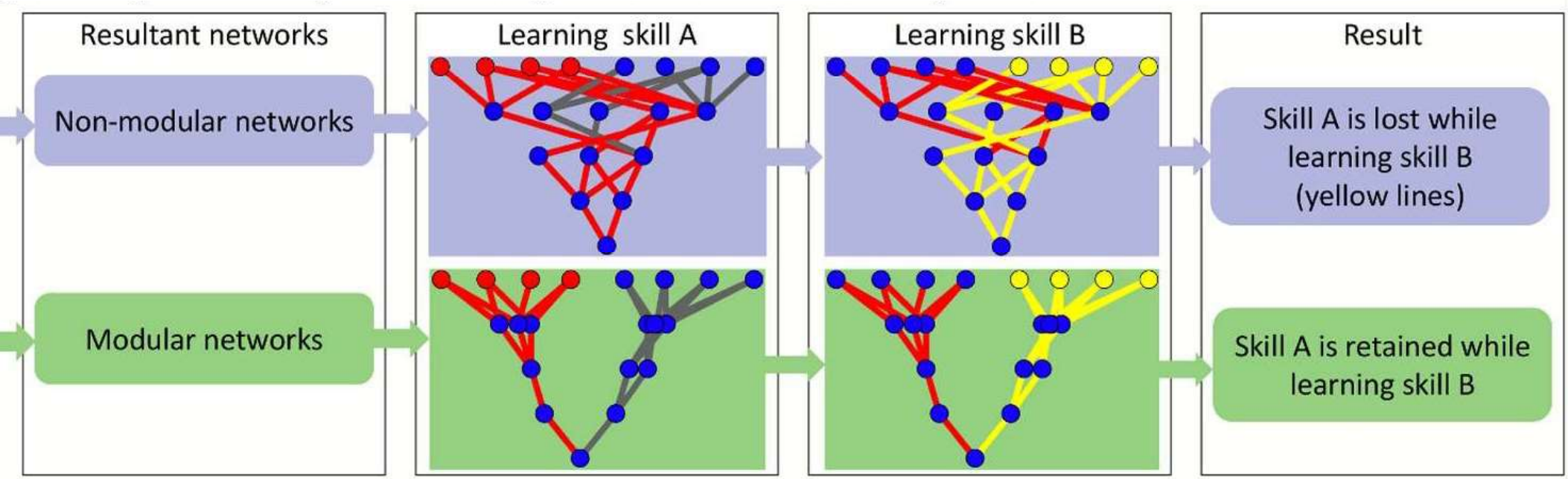
Experimental Setup



Experiment – Hypothesized result



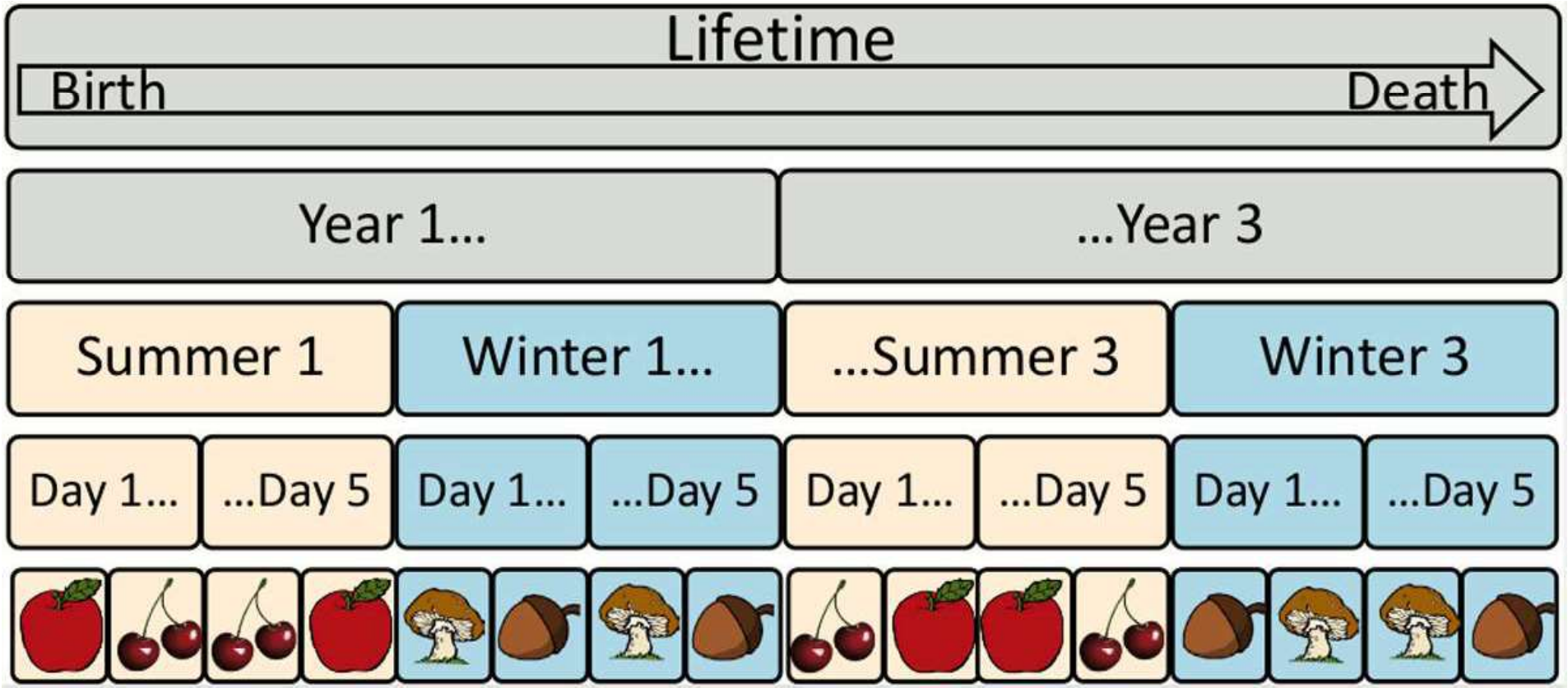
Experiment – Hypothesized results



Evolving Learning Abilities

- Evolution optimized *learning neural networks*
- Each individual was subjected to a number of learning episodes, and awarded a fitness value based on its ability to learn without forgetting
- The learning task abstracted an animal learning food preferences in a seasonally varying environment

A Single Fitness Test



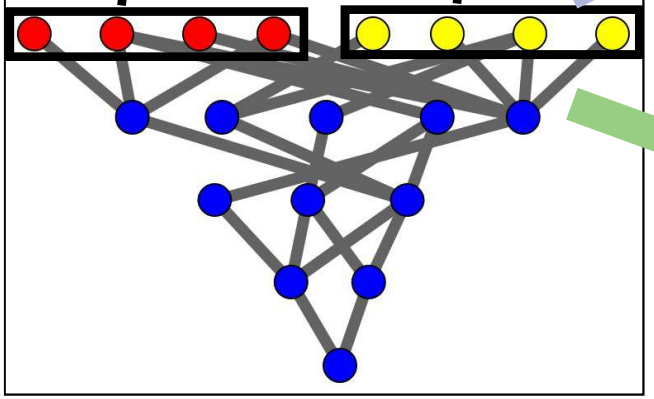
Skill A

Skill B

Goal:
Learning two independent skills, A and B

Inputs for A

Inputs for B



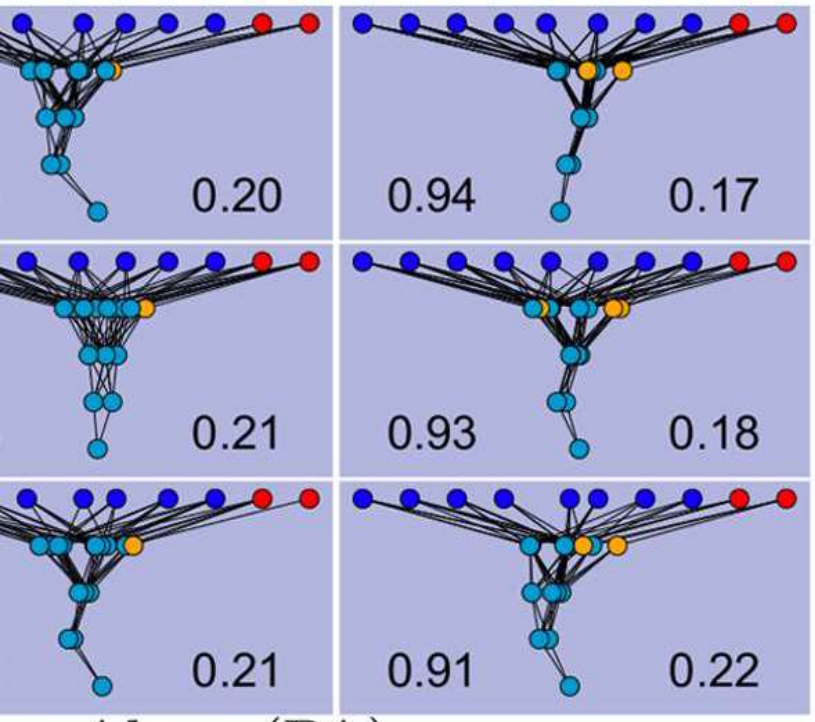
Evolution

Selection on performance alone

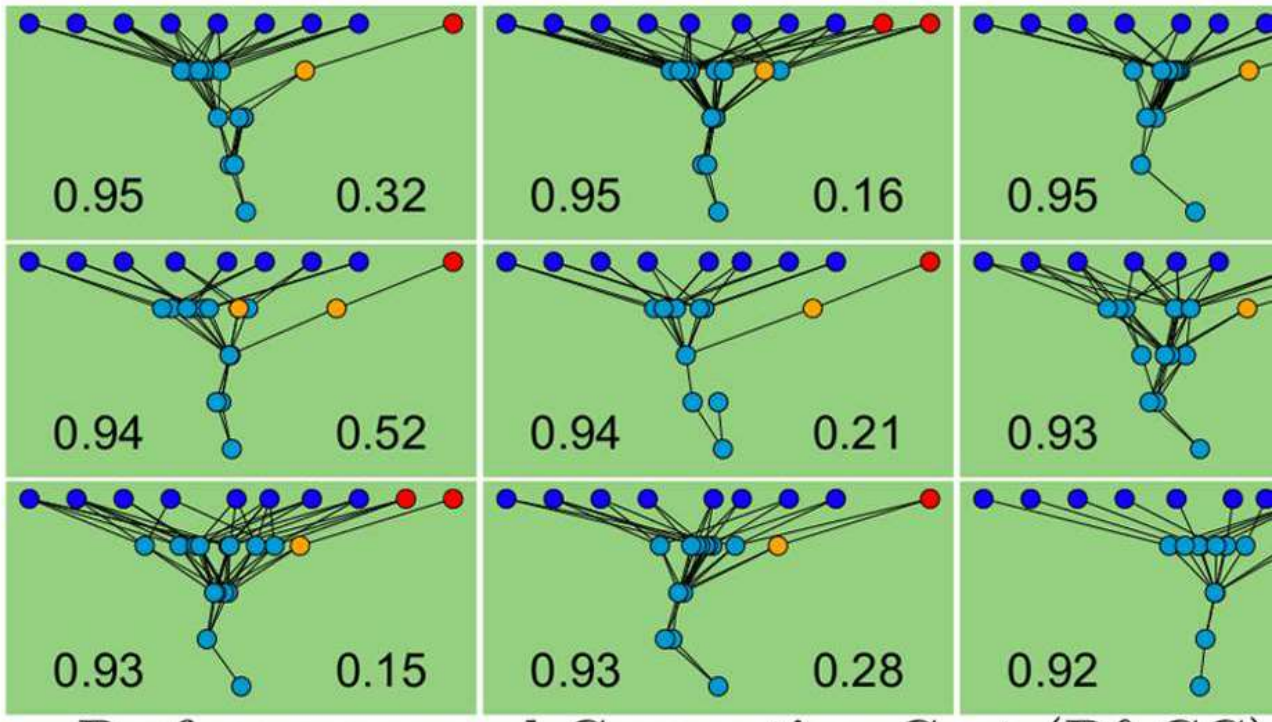
Variation

Selection on performance and connection costs

Variation



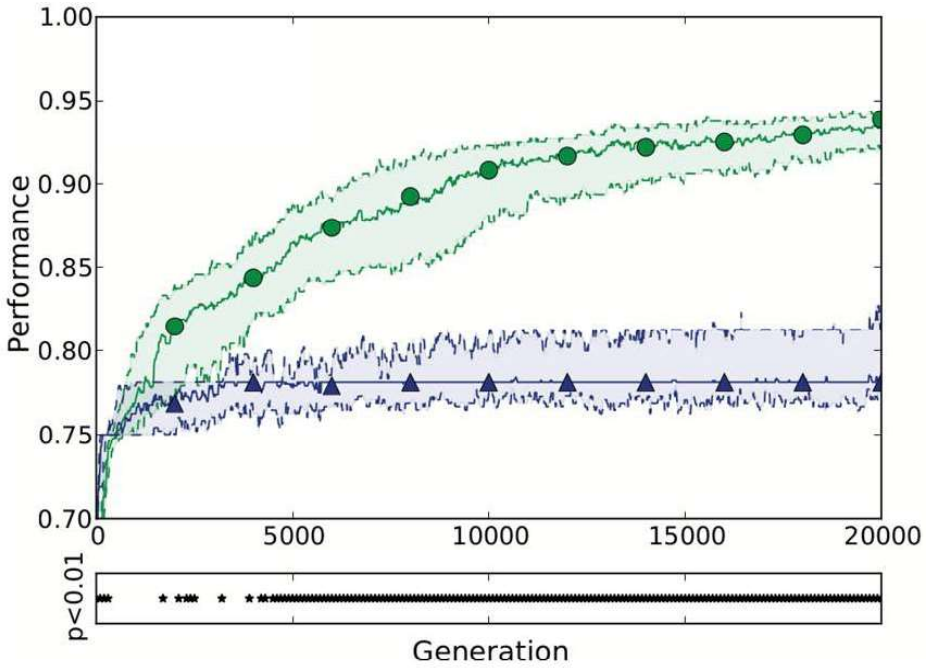
ce Alone (PA)



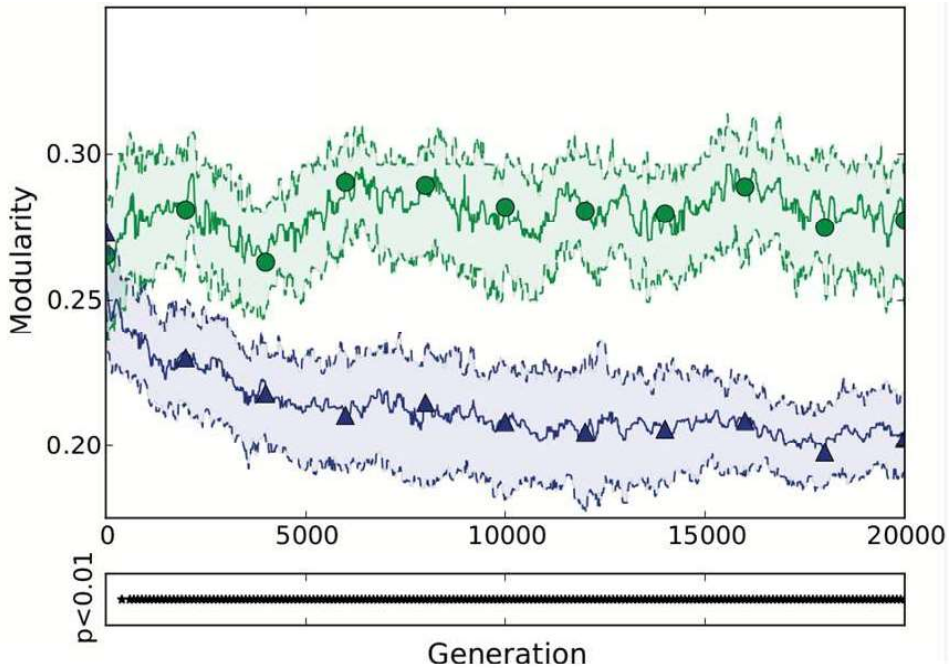
Performance and Connection Cost (P&CC)

Results

Performance



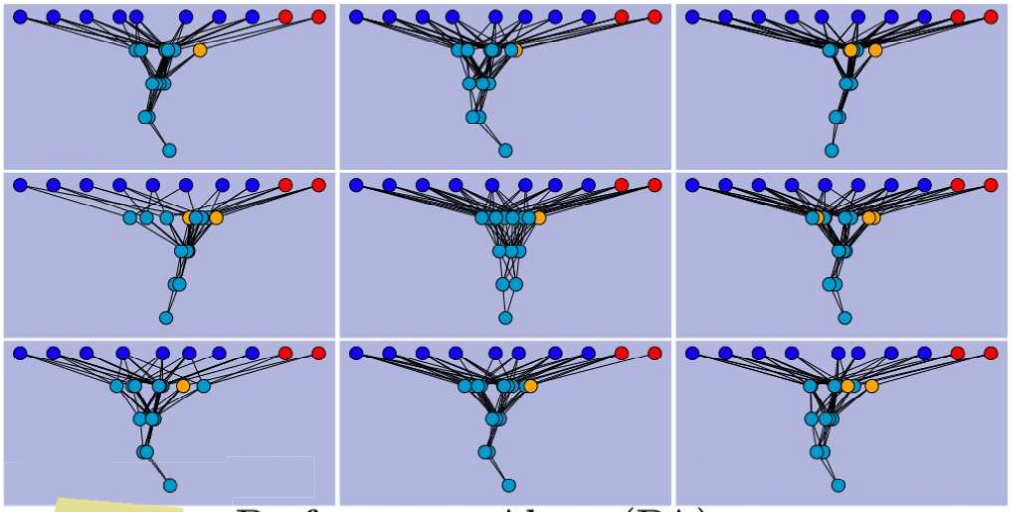
Modularity



Connection Costs

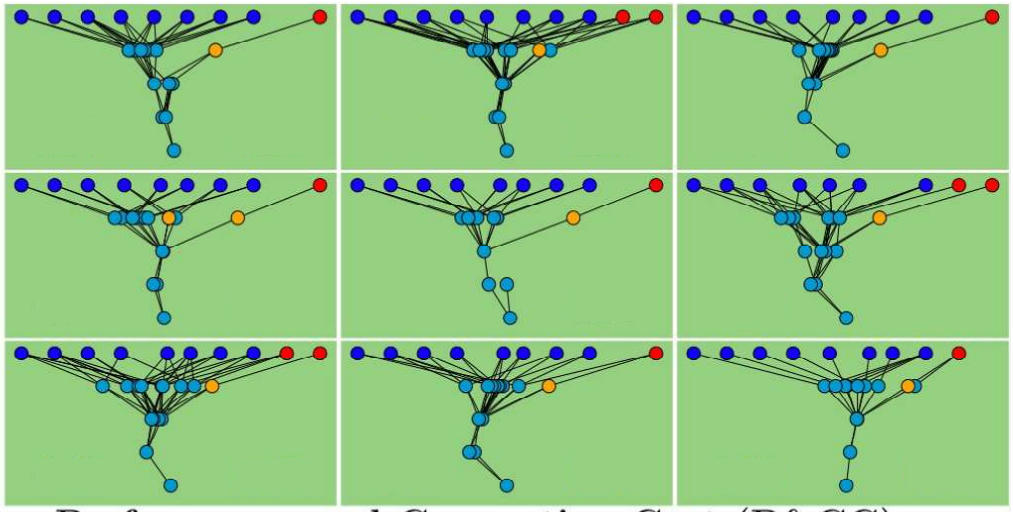
Performance Alone

The Best Networks From Independent Evolutionary Runs

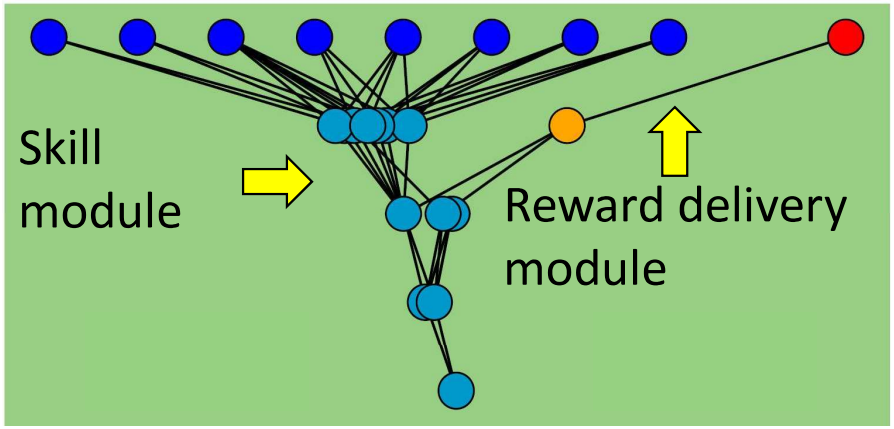


FREE

Performance Alone (PA)

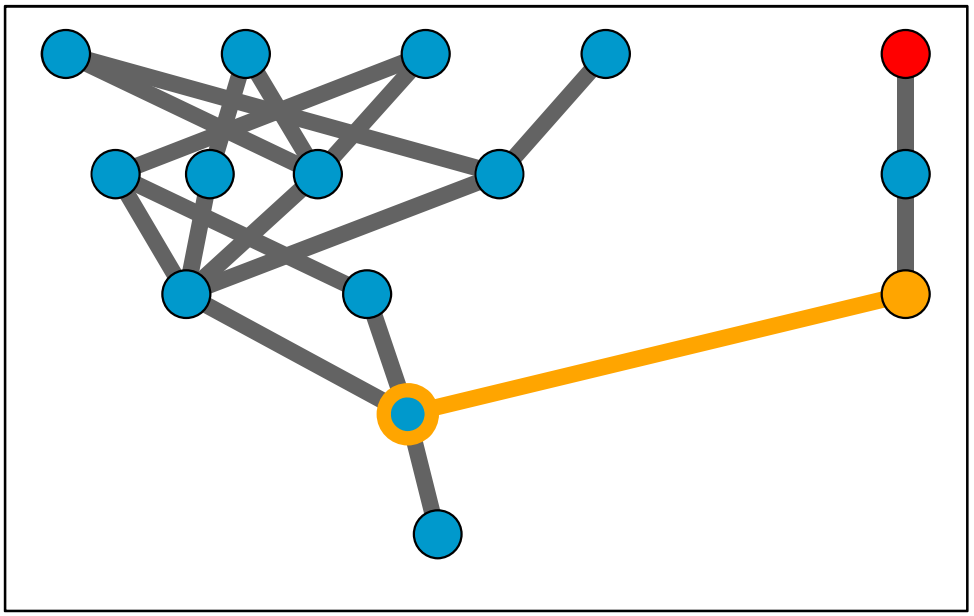


Performance and Connection Cost (P&CC)

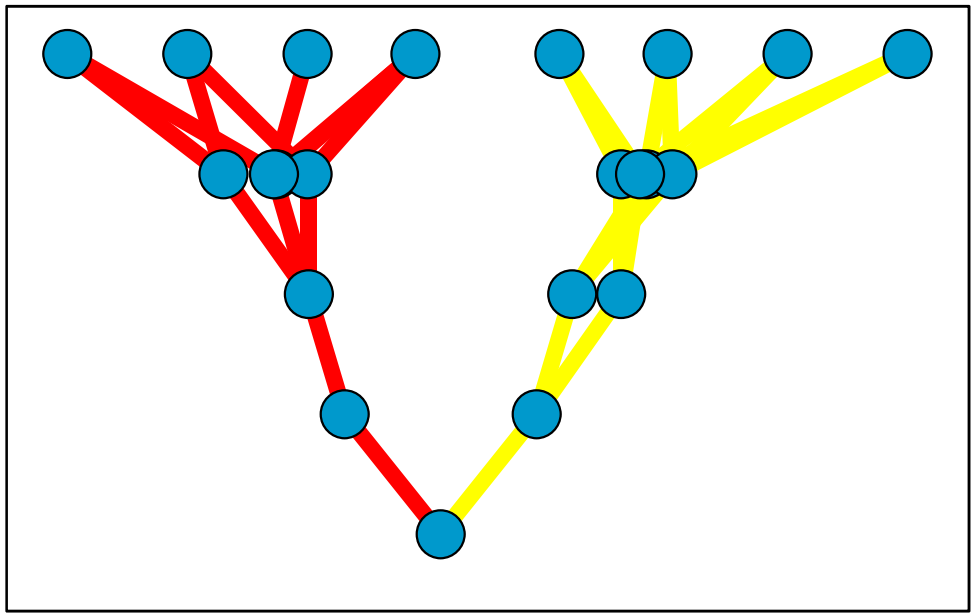


Two Benefits of Modularity:

Separating Skills from Learning Signals

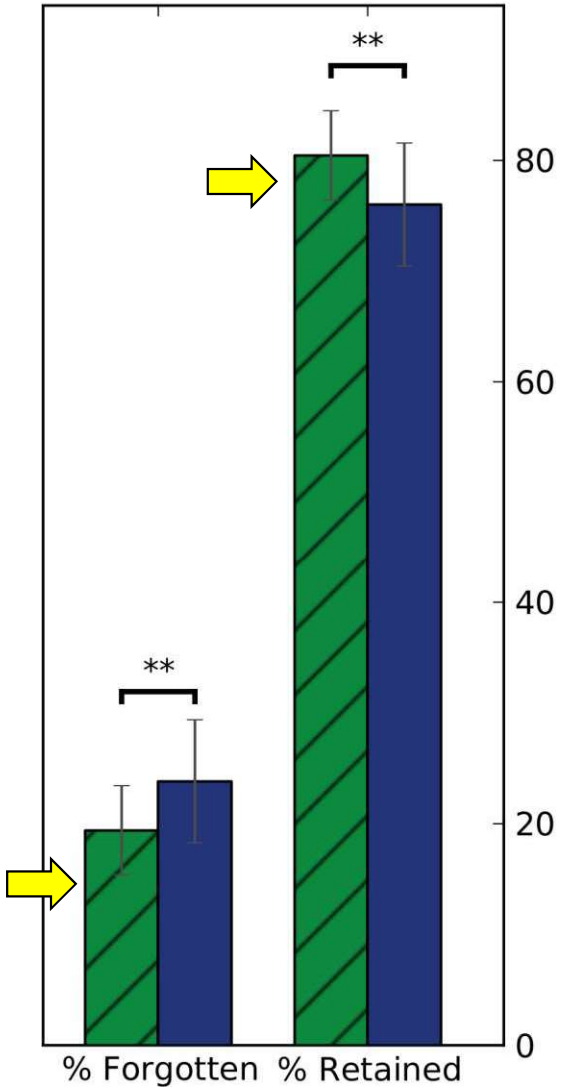


Reducing Interference Between Learned Skills



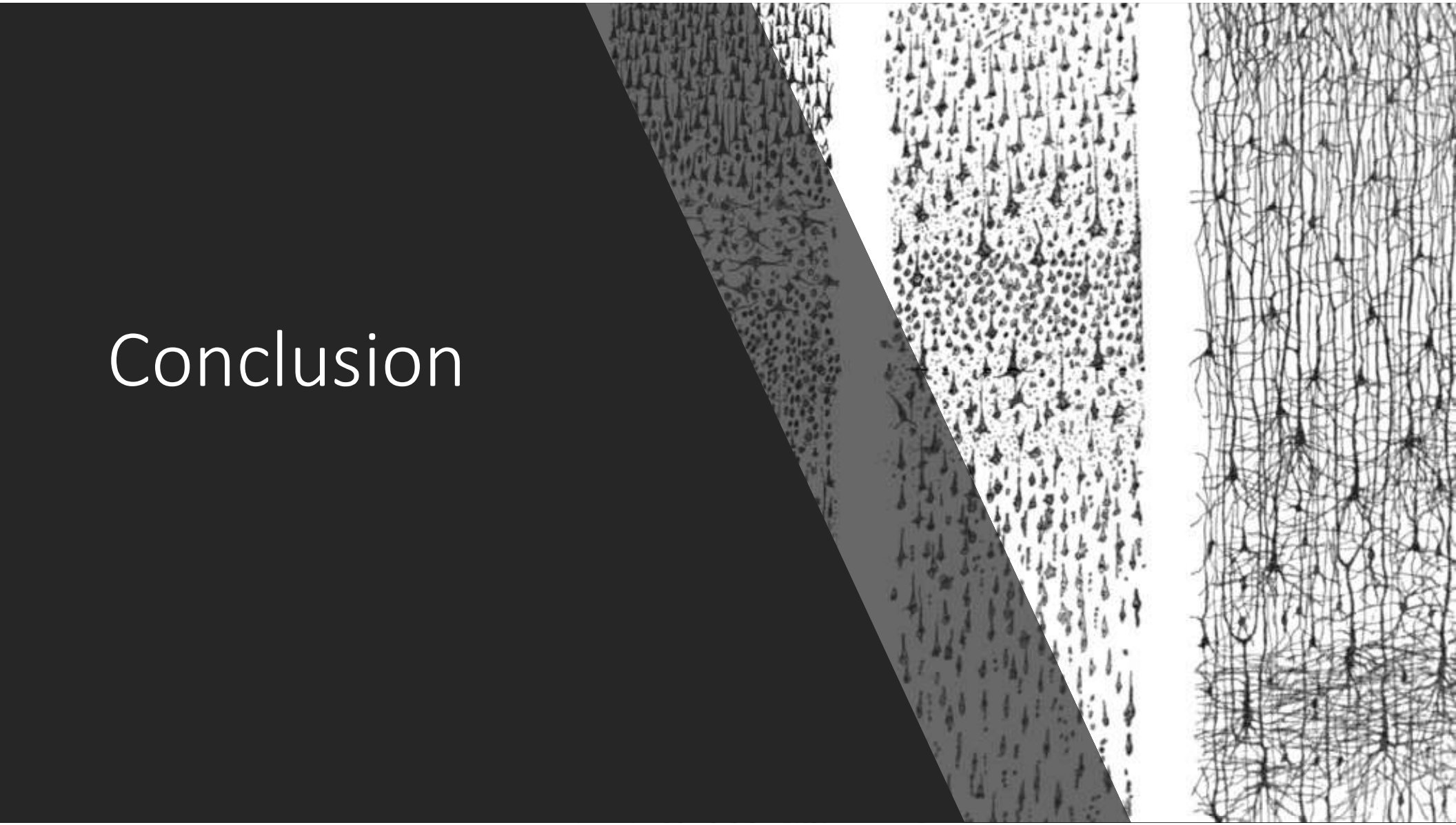
Connection Costs

Performance Alone



Percent of all
Learned Associations

Conclusion



Summary

- Sequential learning is an important and difficult challenge for neural networks
- Adding a connection cost during evolution increases modularity and performance on this task
- Connection-cost individuals are better at retaining learned skills

Important issues for future work

- More complex learning tasks
- Different learning paradigms
- Deeper analyses of the modularity. Is there a functional modularity?
- Separating skills but allowing shared knowledge